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HIGH REFLECTIVITY VALUES OBSERVED IN EQUATORIAL WARM SHOWERS.(U)
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HIGH REFLECTIVITY VALUES OBSERVED IN EQUATORIAL WARM SHOWERS

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1. INTRODUCTION

On a number of occasions radar reflectivity values in excess of +40 dBZ have been observed in warm showers in the vicinity of the Kwajalein Atoll in the Marshall Islands. A warm shower was sampled almost simultaneously by the ALCOR radar and by a Learjet 36 instrumented for cloud physics research. ALCOR and the Lear 36 were operating in the link-offset mode (Barnes, et al, 1974) and obtain radar Z values, drop size distribution and aircraft measured Z values.

2. INSTRUMENTATION

ALCOR is a 5 cm CHIRP radar (Metcalf, et al, 1975) located on Roi-Namur Island in the Kwajalein Atoll. It has a beamwidth of $1/3^{o}$ and radiates 4M Watts. When operating in the link offset mode the PRF is 200, the equivalent pulse length is approximately 40 meters, and the data from the tracking gate are available in real time and as records on magnetic tape. An integrator and color display designed and built for AFGL (Jagodnik, et al, 1975) were adapted to ALCOR to provide color displays of dBZ values for PPI and RHI scans. The link offset mode cannot be operated simultaneously with the color display.

The Lear 36 is equipped with both 1-D and 2-D instrumentation (Knollenberg, 1976) from Particle Measuring Systems (PMS), temperature and dewpoint instruments, a formvar replicator, an on-board computer and digital recorders. A C-band beacon aboard the Lear is tracked with an MPS-36 tracking radar. The ALCOR data-gate is then slaved 3 km ahead of the Lear so that the Lear samples the same volume approximately 30 seconds after the volume is sampled by ALCOR.

3. CLOUD DESCRIPTION

There were no major systems in the area. High thin cirrus clouds were barely visible from the ground, and the Lear obtained PMS particle counts from 11.9 km to the Lear sampling ceiling of 13.8 km. Very thin cirrus was visible above this. The tropopause was at 16.5 km. Cumulus clouds topped out below 4.8 km with an occasional top to 5.5 km. The freezing level was at 5.0 km.

The on-board meteorologist, Dr. Ray Booker of Aeromet, directed the Lear into the most intense shower which he could see. The sampling pass was made at 2.9 km, and the top was estimated to be 4.8 km. Location of the cloud was approximately $9^{o}20'$N, $167^{o}27'$E.

4. RADAR DATA

Figure 1 shows the real time dBZ values versus time starting at 3 hours 25 minutes while operating in the link offset mode. The maximum one-second average value was +40 dBZ obtained at 03:27:51. Range to the data gate was approximately 4.5 km. PPI and RHI color displays taken three hours prior to the sampling run showed warm showers with values in excess of +40 dBZ within 200 km of ALCOR.

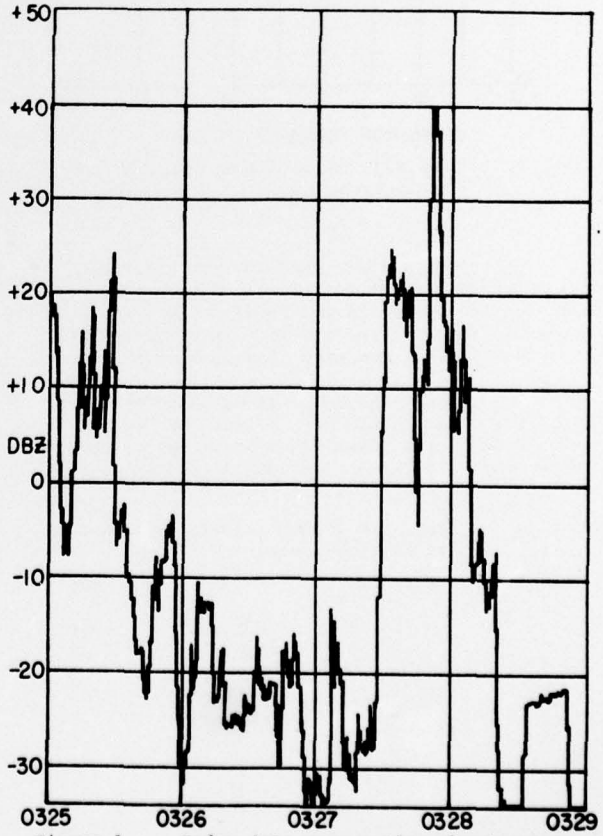

Figure 1. Radar data versus time showing rain shaft in warm cumulus at 03:27:51.

5. AIRCRAFT DATA

The 2-D PMS data were analyzed to give drop size distribution, liquid water content (LWC) values and the dBZ values for the 1.5 seconds closest to the maximum radar dBZ values. Figure 2 shows the normalized drop size distribution obtained from the 2-D Precipitation Probe. The units are number of particles per cubic meter per mm bandwidth. The bimodal distribution with a secondary peak between 1.3 mm and 1.5 mm seems to be real. The sharp cutoff in size at 2.1 mm is real since particles as large as 6 mm have been detected on other flights.

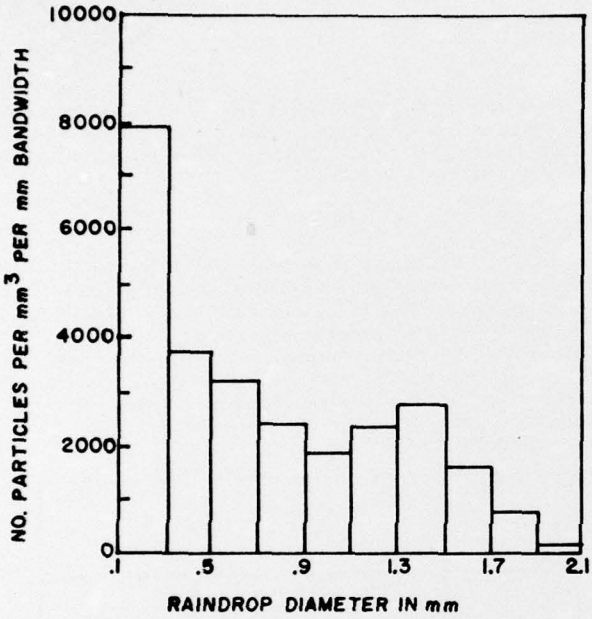

Figure 2. Drop size distribution from the 2-D Precip Probe taken in rain shaft.

LWC values computed from the 2-D data showed 4.7 gm/m^3 for the Cloud Probe and 6.4 gm/m^3 for the Precipitation Probe. Since there is an overlap in size range of these two instruments the actual LWC was computed to be 6.5 gm/m^3.

Using the 2-D data we calculated dBZ values for both the Cloud Probe and the Precipitation Probe for a total value of 43 dBZ. Table 1 shows the calculated Z and dBZ values for the channels in the Precip Probe. Contribution of channels 7, 8 and 9 show the influence of the bimodal distribution.

Table 1. Z and dBZ values calculated from 2-D Precip Probe data.

Channel	Size (mm)	Z	dBZ
1	.1- .3	1.02×10^{-1}	-10
2	.3- .5	2.99	5
3	.5- .7	2.97×10^{1}	15
4	.7- .9	1.24×10^{2}	21
5	.9-1.1	3.64×10^{2}	26
6	1.1-1.2	1.36×10^{3}	31
7	1.3-1.5	4.04×10^{3}	36
8	1.5-1.7	5.04×10^{3}	37
9	1.7-1.9	4.95×10^{3}	37
10	1.9-2.1	1.16×10^{3}	31
Total		1.71×10^{4}	42

There was very little turbulence encountered on this day as the Lear penetrated a number of cumulus clouds. This is typical of almost all cumulus clouds with tops below 10 km which we have sampled in the Kwajalein area. Moderate to heavy turbulence has been encountered in cumulo nimbus clouds with radar tops between 16 and 20 km.

6. DISCUSSION

The Lear penetrated a rain shaft for approximately 1.5 seconds or 130 meters obtaining 6.5 gm/m^3 and +43 dBZ while sampling a volume of 0.2 m^3 with the 2-D instruments. The same rain shaft was sampled by ALCOR but the sample volume was 1.6×10^5m^3, almost six orders of magnitude larger. Considering the difference in sampling volumes, the agreement of the essentially point values obtained by the radar, +40 dBZ, and the aircraft, +43 dBZ, is considered very good.

Using LWC values from the Lear 1-D data and Z values from ALCOR we had previously obtained $M = 0.045Z^{0.547}$ for showers on this day. However, due to an error, all 1-D LWC values in excess of 1 gm/m^3 had been deleted thereby eliminating data taken as the Lear penetrated this rain shaft. Substituting the ALCOR value of +40 dBZ in the 1-D derived equation gives a LWC of 6.9 gm/m^3 which compares extremely well with 6.5 g/m^3 obtained from the Lear 2-D data.

7. CONCLUSIONS

The Z-M relationship derived from LWC values less than 1 gm/m^3 and from dBZ values less than +25 in warm showers on one particular day showed very good agreement when extrapolated to higher dBZ values and larger LWC values. Turbulence in tropical showers was noted to be considerably less than in mid-latitude showers.

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13. ABSTRACT

Warm rain showers with tops below the freezing level were sampled simultaneously by radar and aircraft operating in the link offset mode. High magnitude radar returns were associated with rain shafts in the showers. Turbulence was either non-existent or very light, and the drop sizes obtained by the aircraft showed a bimodal distribution. These data were obtained near Kwajalein, in the Marshall Islands using a 4 M Watt, 5 cm radar and aircraft equipped with hydrometeor sizing and counting instrumentation.

KEYWORDS: Cloud physics, Aircraft sampling, Drop size distribution, Radar reflectivity, Tropical showers, Warm showers

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